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METHOD OF FORECASTING THE TEMPERATURE OF FOG FORMATION

By W. E. SAUNDERS, B.Sc.

This investigation was intended to establish whether the dew-point curve of the radio-sonde ascent at 1500 G.M.T. could be used for selecting a surface temperature at which fog would form. It was known that forecasters had met with some success in fog forecasting by the use of the dew-point curve. Published work relating to the subject seems confined to that of W. C. Swinbank[1]*, who used the lapse rate of mixing ratio (hydrolapse) as one variable in a diagram for deciding whether fog was likely.

It was found that the dew-point curve could be used for this purpose. A comparison showed that fog developed at neighbouring stations at approximately the same temperature at each station. Occasions of no fog were generally those on which the estimated fog temperature was not reached.

Investigation of the controlling parameters.—Fog point is the surface temperature (T_f) at which fog forms. The intention was to find at what height (z)† on the 1500 dew-point curve the potential dew point was the fog point (*i.e.* at what height the constant-mixing-ratio line through T_f intersected the dew-point curve).

It was noted that this level was often very close to the afternoon condensation level of the air at screen level. Since the height (z_1) of this latter level corresponding to any given values of the surface dry-bulb and dew-point temperature is proportional to their difference it appeared that this difference might be a significant parameter.

To test this, 48 cases of fog at Northolt in which there was a representative tephigram available were examined. This represented 63 per cent. of the total occasions of freshly formed water fog in the period August 1948 to November 1949. To restrict the investigation to water fog the criteria visibility of 1,000 yd. or below, and relative humidity 95 per cent. or more, were adopted. The temperature at which fog formed, or at which there was a transition from smoke fog to water fog as defined above, was taken from the hourly or half-hourly

*The index numbers refer to the list of references on p. 219.

†For convenience in working on tephigrams, height (z) is expressed in equivalent pressure difference (mb.).

temperature readings. The height z was read for each fog point from the representative tephigram for 1500, on which dry-bulb and dew-point temperatures were plotted.

For each occasion $(T-T_d)$ was plotted against z (T and T_d were the surface dry-bulb and dew-point temperatures on the 1500 ascent). The curve for z_1 (almost a straight line) was also plotted. For small values of $(T-T_d)$ the curves for z and z_1 were almost identical. With increasing height the curve for z gradually diverged from that for z_1 in the direction of increasing $(T-T_d)$.

It appeared that a closer relation would be likely if some correction were applied which had the effect of making a small reduction in the numerical value of $(T-T_d)$. A corrected surface temperature (T_c) was then substituted for T. T_c was the surface temperature given by following the dry adiabatic of the lowest potential temperature in the layer affected by diurnal heating to the surface pressure. T_c effectively ignores superadiabatic layers near the surface, and must correspond very closely with the theoretical maximum temperature derived by E. Gold[2]. The writer found it necessary to apply a similar correction in earlier work on cooling[3]. For purposes connected with the afternoon tephigram T_c appears appreciably more significant than the actual maximum temperature.

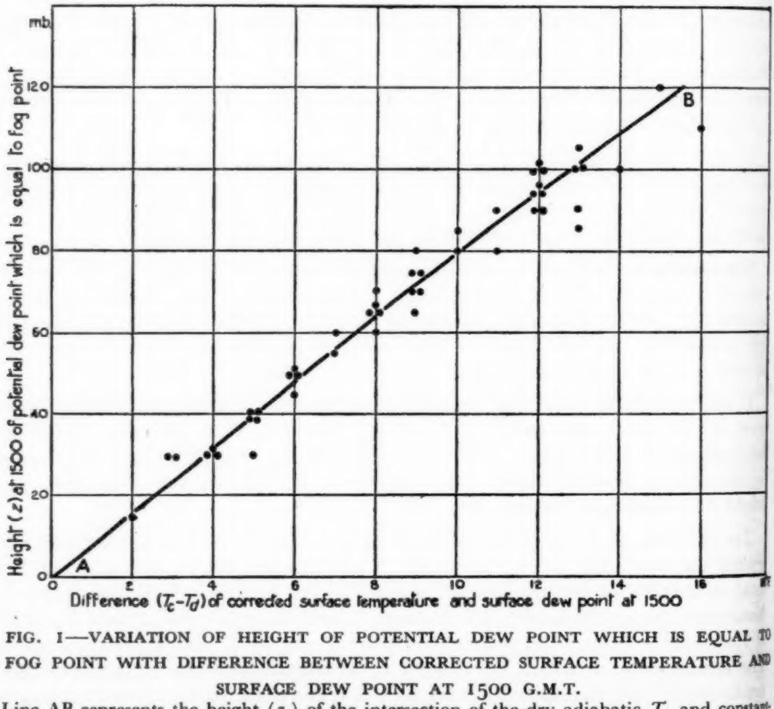


FIG. 1—VARIATION OF HEIGHT OF POTENTIAL DEW POINT WHICH IS EQUAL TO FOG POINT WITH DIFFERENCE BETWEEN CORRECTED SURFACE TEMPERATURE AND SURFACE DEW POINT AT 1500 G.M.T.

Line AB represents the height (z_1) of the intersection of the dry adiabatic T_c and constant-mixing-ratio line through T^d corresponding to values of (T_c-T_d)

The results of plotting $(T_c - T_d)$ instead of $(T - T_d)$ against z are given in Fig. 1 by the dots. AB is the line giving the heights z_1 of the intersection of the dry adiabatic through T_c and the moisture isopleth through T_d corresponding to the values of $(T_c - T_d)$ along the abscissa; it is not the mean of individual values of z. It is seen, however, that AB is practically identical with the mean of the plotted values of z. Hence, for practical purposes, $z = z_1$, and T_f is the potential dew point at the level of the intersection of the dry adiabatic through T_c and the constant mixing ratio line through T_d. The mean curve for z may still diverge a little from that for z_1 above a value 12°F. of $(T_c - T_d)$. The number of cases in this region is too small to warrant a definite conclusion on this.

The result suggests that the depression of fog point below the afternoon dew point is proportional to the lapse rate of potential dew point with height, and approximately proportional to the depression of dew point below the temperature at the time of maximum temperature. It is of course probable that other parameters, such as state of ground, which it has not been found necessary to take explicitly into account, are in fact contributory in setting up the 1500 dew-point curve, and so influence the result.

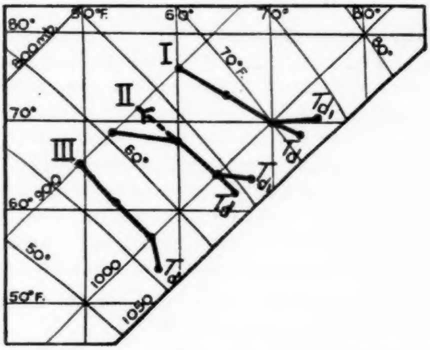


FIG. 2—DEW-POINT CURVES AT 1500 G.M.T.

The dew-point curve at 1500.—Fig. 2 gives the three significant types of dew-point curve which were encountered in the work described in the previous section.

Type I.—As a result of heating and turbulence, moisture has become distributed to give constant hydrolapse. The surface value of the dew point may be in alignment with the higher values (T_d), or may be displaced a little to the right (T_{d_1}) in harmony with a superadiabatic lapse rate of the dry bulb.

Type II.—The hydrolapse increases above some point within the layer concerning us. This may occur when marked subsidence extends down to this level, or where two air streams of different origin are involved, such as a dry continental stream flowing over a moister south-south-west current over southern England. To obtain a result consistent with that obtained for Type I dew point, the portion of the dew-point curve unaffected by mixing with the drier air had to be produced upwards in its own direction, and the potential dew point taken along this corrected dew-point curve.

Type III.—The dew-point lapse rate in the lowest layer is less than that prevailing above. This case may be subdivided as follows:—

Type IIIA.—The dry bulb fails to attain the dry-adiabatic lapse, or by 1500 the dry bulb has fallen slightly below a dry-adiabatic lapse previously attained, and the dew point has fallen with it. These cases are dealt with as for Type I.

Type IIIB.—This dew-point distribution is occasionally found even with dry-adiabatic lapse reached or exceeded by the dry bulb, when turbulence is exceptionally slight during the afternoon. This is characterised by very small values of the wind shear from the ground to 900 or 850 mb. In these cases it appears that surface moisture does not become completely mixed, and the afternoon dew point is itself the fog point. On several successive days during the last week of August, 1949, the synoptic situation was exceptionally stagnant. On one occasion the wind speed was only 2 kt. to 850 mb. at Larkhill. Visibilities of the order 2–3 miles reported during the afternoons over southern England might, having regard to the time of year, be taken to indicate that haze, as well as moisture, was not being freely mixed. Thick night fogs occurred, with little or no depression of dew point from afternoon values.

Some tests of the result obtained.—For the occasions which were used in the preparation of Fig. 1, the actual fog temperatures at Northolt (which were usually obtained without difficulty within one degree from the half-hourly temperature readings) were plotted against the estimated T_f derived from AB of Fig. 1. For nights of clear sky and light wind when no fog formed the minimum temperature was plotted against the estimated T_f. The results, given in Fig. 3, show that when fog formed, given a representative tephigram, the temperature of fog formation would have been forecast within one degree on 44 occasions out of 48. Of 18 occasions of no fog, the estimated T_f would have been reached four times. These were occasions of ground fog but not general fog.

Fig. 3 suggests that the absolute value of T_f makes little difference to the result, at any rate over the range 25° to 60°F.

The results of a comparison between estimated and actual fog temperatures at neighbouring airfields for those occasions during the period August 1948 to May 1949 when a representative sounding was available are given in Table I.

TABLE I—COMPARISON AT STATIONS IN AREA WEST OF LONDON

Station	Occasions when fog formed		Occasions (light wind and clear sky) of no fog	
	Actual T_f within $\pm$ 1°F. of estimated T_f	Actual T_f differed from estimated by more than $\pm$ 1°F.	Estimated T_f not reached	Estimated T_f reached
	number of occasions			
South Farnborough	21	2	18	3
London Airport	25	2	20	1
Hendon*	17	2	21	1
Bovingdon	18	3	19	1

*Station closed at some periods

Within the $\pm 1°$ limit there appeared a tendency for fog to develop at $+1°$ at London Airport, and at $-1°$ at South Farnborough.

Mr. E. T. Baker tested the method at Hemswell and Waddington on eleven nights in September to November 1949. There were six fog occasions. In four of these water fog appeared to form at within $\pm 1°$ of the estimated T_f. In two cases fog formed at a temperature several degrees higher than T_f estimated from the Downham Market sounding, but it was afterwards noted that there had been advection of moister air from the south in both cases. In the first Larkhill would have given an exact result, while in the second a sounding made intermediately between Larkhill and Downham Market would have served. On each of five potentially foggy nights during which no fog formed the night minimum temperature was above the estimated T_f.

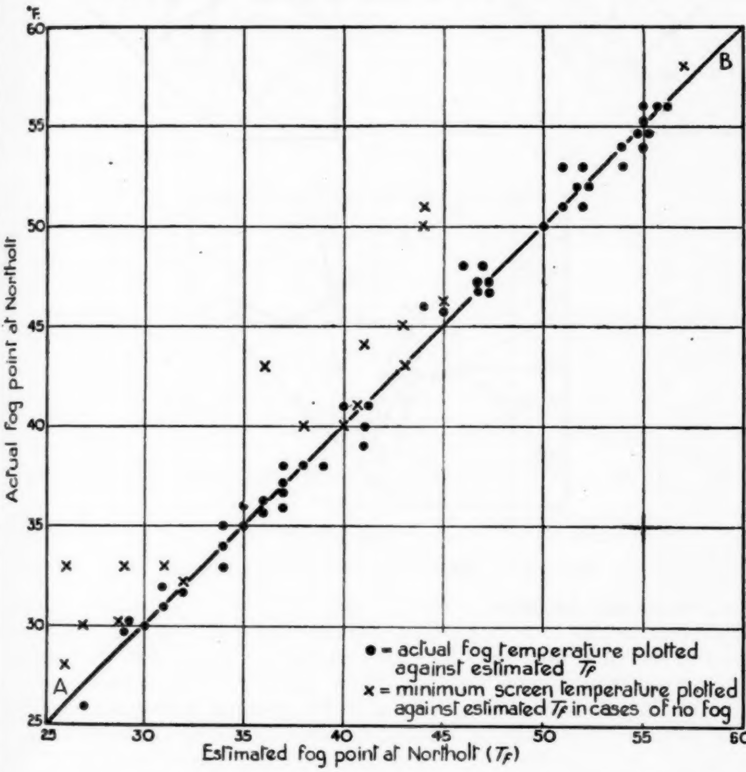
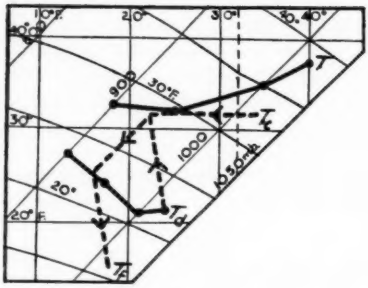


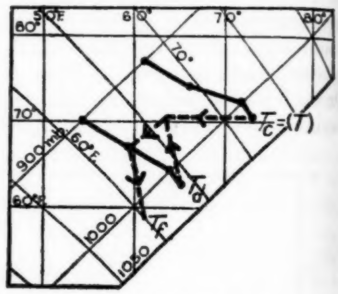
FIG. 3—COMPARISON OF ESTIMATED AND ACTUAL FOG TEMPERATURES
AB is the line of least error in actual Fog cases

Suggested forecasting procedure.—(*a*) *Use of the tephigram.*—In Fig. 4 full lines indicate the dry-bulb and dew-point curves on the 1500 tephigram, and broken lines the construction for T_f. In Type II the drying out often appears to work down to below the inversion. If any depth of moist air remains at 1500 T_f must be derived from extension of the dew-point curve in the moist air.

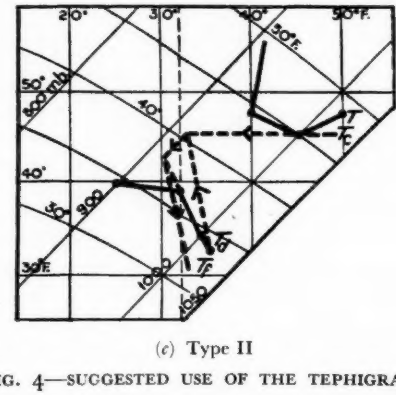
Cases were noted where dry air penetrated down to only 20 or 30 mb. above the ground at 1500, yet T_f was clearly the value corresponding to the moist air at all stations. In such extreme cases, to use so shallow a layer from a routine sounding would obviously invite error, and it is better to use the surface dew point as T_f. Type IIIA calls for no comment. Type IIIB is the special case referred to on p. 216, where the surface dew point is the fog point.



(*a*) Type I



(*b*) Type IIIA



(*c*) Type II

FIG. 4—SUGGESTED USE OF THE TEPHIGRAM

(*b*) *Representative tephigrams.*—The question of whether a particular sounding is representative has to be determined from the synoptic situation with special regard to the wind direction and speed. An ascent up-wind in the same air mass is generally representative, but possible advective changes have always to be looked for and allowed for. With no ascent up-wind, a sounding elsewhere in the same airstream may be satisfactory if the surface dew points are within one degree. The advection of moist sea air presents a special problem: T_f will be higher in air which has been advected from the sea than in air which has been heated over the land, and the tephigram in the sea air must usually be estimated. In a few cases the afternooon sounding is rendered non-representative by rain preceding fog.

(*c*) *The case of T_f below freezing.*—For the area considered, and for the range 25–32°F., the results suggest that when T_f is reached thin fog forms with visibility of the order 600–1,000 yd., provided there is not also thick smoke.

(*d*) *Ground and adjacent fog; delayed fog*.—Owing to irregular cooling, ground fog or adjacent fog, with visibilities 1,000–2,000 yd., is often reported with the screen temperature still several degrees above T_f. Occasionally T_f is reached and fog formation delayed for several hours, perhaps owing to lack of turbulence. The period after sunrise will obviously be critical if T_f has been reached without fog forming.

(*e*) *Smoke fog*.—Smoke fog depends upon the parameters wind direction and speed, vertical temperature gradient, time of day, day of week and season of year, and can exist with relative humidity as low as 60–70 per cent. Consequently smoke fog cannot be dealt with by a numerical addition to T_f, and it must be dealt with separately.

(*f*) *Stratus cloud*.—If turbulence is sufficient to cause stratus cloud to develop at height z_2, instead of fog, it should be possible to forecast the surface temperature (T_s) at which stratus will form by drawing the constant-mixing-ratio line through T_f to this height. The dry adiabatic intersecting this mixing-ratio line at height z_2 should then reach the surface at T_s. This method has given satisfactory results in some cases, and appears worthy of further trial.

Acknowledgment.—The writer is indebted to Dr. R. C. Sutcliffe, at whose suggestion the work was undertaken, and to Mr. G. A. Corby and Mr. J. M. Craddock, for discussions and suggestions at various stages, and to Mr. E. T. Baker for testing the method in Lincolnshire. The forecasting staff at Northolt have been most helpful in testing the method.

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CAMBRIDGE UNIVERSITY ICELAND EXPEDITION OF 1947
Meteorology

By D. S. BROCK, B.A.

The Cambridge Iceland Expedition 1947, led by I. R. Menzies, went to the north-west peninsula of Iceland to undertake glaciological and entomological work on the south-west margin of the Drangajökull ice-cap. Meteorological observations were maintained for the period from August 5 to September 5, 1947, at the Base Camp approx. 66°5′N. 22°10′W. The Stevenson screen was erected on a low heap of moraine some 200 yd. (180 m.) from the Camp at an altitude of 1,125 ft. (343 m.) above sea level. Observations were taken throughout the period at 1000, 1400, 1800 and 2200 G.M.T. Pressure was read from a pocket aneroid at the Base Camp at the same periods: weight prevented the inclusion of a barograph. Records were made of the daily maxima and minima, wet- and dry-bulb temperatures, the direction and strength of the wind, the amount and type of cloud cover, and the amount of precipitation.

The Base Camp station lay in a wide north-south valley with gently sloping sides, rising to 2,140 ft. (652 m.) on the west and 1,370 ft. (418 m.) on the east. To the south the gentle slope extended for three-quarters of a mile (1,200 m.) before plunging down to the south-westerly flowing Selá. To the north-east

lay the south-west corner of the Drangajökull ice-cap at a distance of $2\frac{1}{2}$ miles (4 Km.), rising to a crest of 2,788 ft. (850 m.) with an average gradient of 1 in 11.

The month was characterised by the passage of a number of depressions moving north-eastward up the Denmark Strait taking an average of four days to travel from Cape Farewell to north of Scoresby Sound. The average cloud cover during daylight hours for the month was 8 tenths and owing to the persistence of low cloud the direction of upper winds could only be obtained on very few occasions; on all but two of these the direction coincided with that of the surface winds measured at the station. It is considered, therefore, that the lie of the wide and shallow valley had little effect on the local winds at 1,125 ft. (343 m.) which generally crossed it at an angle. The farmers on the fjord coast to the south-west of the ice-cap usually relied on the NE. winds off the ice-cap to bring them clear fine conditions for their hay harvest, but the summer of 1947 was a particularly poor one for Iceland and, in the north-west peninsula, there was a greater proportion of rain-bearing SW. winds than NE. winds in the month that observations were taken. The depressions tended to travel slowly up the Denmark Strait, in some cases remaining several days to the west of Iceland, only to be rapidly replaced by further depressions as soon as they had passed to the north. Their presence accounted for a greater preponderance of SW. winds than is usually met with in the Icelandic summer.

Winds from the south-west and south-south-west prevailed for nearly three times as long as those from the north-east. These SW. winds tended to be stronger in character than those from other directions. The winds were invariably stronger during the daytime than during the night. In the thirty days from August 6 to September 4, there were only four occasions on which the average wind speed for the twelve hours 2200–1000 was greater than that for the period 1000–2200. The steadiness of the wind on certain days was particularly noticeable: from 2200 on August 16 to 2200 on August 17 the 24-hr. average was 22·9 m.p.h. (37 Km./hr.). The highest recorded wind speed over a one-minute interval (at 1400 during this period) was 33 m.p.h. (53 Km./hr.), whilst the highest 4-hr. average (from 1400–1800) was 26·5 m.p.h. (42·5 Km./hr.).

The two highest temperatures, 63·5°F. (17·5°C.) on August 22 and 62·5°F. (17°C.) on August 26, were associated with the passage of warm fronts from south to north and with southerly winds. The lowest temperature, 36·5°F. (2·5°C.) on the night of August 19–20 was associated with the presence of a depression on the east coast of Greenland to the west of Iceland and with the cool SW. winds of polar origin associated with it. The average minimum temperature at 1,125 ft. (343 m.) between 2200 and 1000 was 43·1°F. (6·1°C.): there is evidence to show that, even in August, the temperatures in the bottoms of the valleys are considerably lower than this. On nights with still air and clear skies, frost was observed in the valleys. Although the mean daily temperature fluctuates considerably over the period there does not appear to be any consistent rise or fall during the month.

The total rainfall for the month was 1·67 in. (42·46 mm.), 90 per cent. of which fell in the first half of the period. The days where no rainfall is recorded were often overcast with a steady drizzle throughout the daylight hours which was not recorded in the rain-gauge. Twelve days are recorded without rain,

but on only five of these did the sun shine for any considerable time. On the night of August 18 snow was experienced on the ice-cap at 2,800 ft. (854 m.) with a SW. wind of estimated speed 50 m.p.h. (80 Km./hr.); the temperature at 1,125 ft. (343 m.) at this time was 37·5°F. (3·1°C.) and the average wind speed during the night was 21 m.p.h. (34 Km./hr.).

TABLE I—PERCENTAGES OF OBSERVED CLOUD TYPES DURING DAYLIGHT HOURS FOR THE MONTH AUGUST 5 TO SEPTEMBER 5, 1947

Cloud type	Over the Base Camp and fjords	Over Drangajökull
	per cent.	
Stratocumulus	25·6	10·4
Cumulus	24·8	22·4
Stratus	16·0	45·6
Altostratus	14·0	6·4
Nimbostratus	8·8	8·0
Altocumulus	5·2	0·8
Cirrocumulus	1·6	0·8
Cirrus	1·6	2·4
Cumulonimbus	1·6	0·0
Cirrostratus	0·8	0·8
Nil	0·0	2·4

The above table shows the percentages of cloud types during daylight hours. The figures for Drangajökull illustrate those conditions that exist over the south-west side of the ice-cap. Conditions on either side would vary considerably as was evidenced by journeys over the ice-cap. With a NE. wind, clouds would pile up on to the eastern side of the ice-shed whilst the west side was clear. With a SW. wind the ice-cap tended to be covered on both sides but the cloud level on the eastern slopes was higher than that on the west. The amount of altostratus shown over the Base Camp is somewhat misleading as, in fact, whenever a break occurred in the stratocumulus a higher layer of altostratus was usually observed.

The figures for humidity do not show much more than an expected lowering during the warmer hours of the day. Only on one occasion did the relative humidity fall below 60 per cent. and the average was in the neighbourhood of 82 per cent.

On the southern half of Drangajökull in late August 1947 the firn line was found to extend down to 2,450 ft. (747 m.) on either side. The ice-shed, which in this portion runs north-west—south-east, lies 3½ miles (5·6 Km.) from the south-west edge of the ice and 2 miles (3·3 Km.) from the north-east edge. The average gradient of the south-west slope is 1 in 11 and that of the north-east slope is 1 in 7. It will be seen, therefore, that there is a greater accumulation of firn on the south-west slopes than on the north-east slopes, and this is confirmed by the presence of large drifts on the south-west sides of the nunataks. This accumulation is due to the predominance of NE. winds in the area. In recent years, depressions passing eastward across the Atlantic have tended to travel to the south of Iceland both in summer and in winter and the NE. winds resulting from them have struck the eastern flanks of Drangajökull. The sudden rise of 3,035 ft. (925 m.) accounts for the amount of orographic precipitation and the distribution of snow in considerable volume on the south-west flanks. Thirty-three miles (53 Km.) to the south-west of Drangajökull lies the summit of Gláma, which is the same height as Dranga and of similar area. At the begin-

ning of the century this peak carried an ice-cap but now only has large permanent snow patches on its flanks. It is considered that the reason why Dranga still has an ice-cap and Gláma has not is that the former has received far greater winter precipitation than the latter, and that consequently an amelioration of the climate of the region will have had a proportionately greater effect on the speed of ablation of the Glámajökull compared with the Drangajökull.

The Expedition wish to express their thanks to Professor Gordon Manley, M.A., M.Sc., for his assistance and advice on many matters, and also to the Royal Meteorological Society, the Meteorological Office, Air Ministry, and the Vedurstofan Reykjavík for the loan of instruments.

OXFORD UNIVERSITY ICELAND EXPEDITION OF 1947

Meteorology

By C. SWITHINBANK

The expedition spent seven weeks in south-east Iceland, and was engaged mainly in botanical work. Meteorological instruments were lent by the Meteorological Office, Air Ministry. A continuous programme was carried out at a Base Camp near the south coast situated at approximately 63°55′N. 17°45′W., and a small party spent 38 days on the ice-cap Vatnajökull. At the Base Camp, observations were taken three times daily, at 0800, 1400, and 2100 G.M.T., from July 29 to September 8. The instruments used were maximum, minimum, and ordinary thermometers; and a hair hygrograph. Pressure was read simply from a pocket aneroid and rain was only roughly estimated. General weather conditions, visibility, and cloud cover (in tenths) were recorded. Wind direction and speed were estimated. In addition to the work at the Base Camp, a few scattered observations were taken on the ice-cap between July 31 and August 28. In this case the instruments used were wet- and dry-bulb thermometers, and a hand anemometer.

Observations at the Base Camp.—The Base Camp station was situated at the farm Kálfafell, on the edge of the coastal plain. The sea lay 15 miles to the south over a flat, low lying area. To the east and to the west a line of cliffs, from 300 to 2,100 ft. in height, rose abruptly from the plain. These were dissected by broad, deep valleys, running in a north-south direction. At the head of these valleys, 10 miles from Kálfafell and at an altitude of 1,900 ft. above sea level, was the edge of the ice-cap. The screen was set up in an exposed position at an altitude of 170 ft. above sea level.

During the period of observing, pressure usually fell towards the south-west. A number of depressions passed north-eastward up the Denmark Strait, and one, between September 4–6, passed immediately to the south of Iceland moving in the same direction. The weather at Kálfafell is certainly not determined solely by the influence of these depressions. Local influences continually interfere. For instance, it is probable that the high land to the north, together with the very extensive ice mass of Vatnajökull, frequently causes katabatic winds to disturb the cyclonic winds; that the temperature is affected by the North Atlantic Drift, which moves along this particular part of the coast; and that the rainfall is increased by the rapid rising of the land behind the coastal plain.

The percentage frequency of observed wind directions is shown in Fig. 1. It seems probable that the air stream passing over the station was often of no great depth, and that local topographical features accounted for some deflection

Similarly, the high percentage of calms observed has no particular significance, since Kálfafell receives considerable protection from a steep slope immediately to the north. The preponderance of NE. and E. winds is contrary to the direction of the main air stream over Iceland. The average cloud cover was 8 tenths; no two consecutive observations recorded blue skies. On some occasions when winds were blowing in from the sea an orographic cloud formed immediately above a 2,100-ft. high cliff near the Base Camp, and remained stationary while the main cloud layer, at a considerably greater altitude, moved northward. On one such occasion rain was seen to be falling from the stationary cloud.

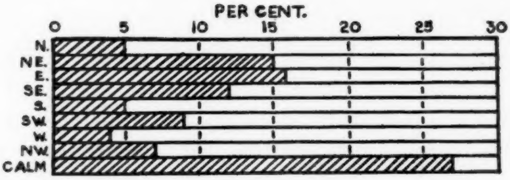


FIG. 1—PERCENTAGE FREQUENCIES OF SURFACE WIND AT BASE CAMP (APPROX. 63°55′N., 17°45′W.), JULY 29–SEPTEMBER 4, 1947

The mean of the temperature measurements at the daily times of observation over the period was 53·1°F., and the mean daily range of temperature was 9·7°F. The highest recorded temperature was 73·0°F. on August 3, this being associated with the passage of a warm front. The lowest recorded figure was 38·2°F. on the night of August 27–28. It appeared to be associated with a marked inversion of temperature, the night being one of the very few during which the air was still and the sky was cloudless. It is interesting to note that in spite of a katabatic movement of air down the valleys from the ice-cap which was quite common at night-time, and in spite of the favourable conditions for inversion which are found in the valleys themselves, no frosts were recorded at the Base Camp, neither were any signs of frost noted in the valleys. Katabatic winds were shallow, as was occasionally shown by the direction of movement of the cloud cover, and they were easily displaced by winds associated with the passage of depressions.

The narrow strip of land lying between the southern ice-caps and the sea is the wettest inhabited region of Iceland. The nearest observing station at Fagurhólsmýri, 32 miles to the east, has a mean annual rainfall of 74 in. July–August is the driest period of the year, and September–October is the wettest. During the period of observation at the Base Camp, 9·4 in. were recorded, rain falling on 28 out of 37 days. Most of the wet weather occurred when winds were blowing in from the sea, and took the form of prolonged showers or light continuous drizzle. The biggest downpour was on August 14, when 1·13 in. fell before 0800. The wind at the time was a moderate south-westerly.

Observations on Vatnajökull.—The weather on the ice-cap from July 31 to August 28 was predominantly mild and very wet. No single day was without both rain and thick fog. The winds were on the whole stronger than those recorded at the Base Camp. This was no doubt largely due to the relatively exposed position of the ice-cap stations. The records show that 65 per cent.

of the winds were northerly, a singularly high percentage in comparison with the frequencies at the Base Camp. It is possible that this is the result of a partly permanent outflow of cold air from the centre of Vatnajökull*, that same movement of air which gives rise to the katabatic flow down the valleys at night. No high wind speeds were recorded, the highest over any one-minute period being 25 m.p.h. on August 9.

The mean day temperature was 38°F., the mean daily range being small. The maximum temperature was 46°F. on August 11; the minimum was 30°F., slight frost being observed during several nights.

The total rainfall over the period was not recorded. Throughout several days and nights rain was practically continuous, and during others heavy and prolonged showers alternated with wet mists. A particularly bad spell of weather from August 8–10 brought persistent winds of force 5 and a total of 5·0 in. of rain.

As a result of the practically continuous fog on the ice-cap, no estimation of cloud cover could be made. During approximately 9 tenths of the period the visibility was less than 120 yd. On the few occasions when the clouds lifted, visibility was excellent under the influence of a fresh northerly breeze. Relative humidity was consistently high, the average at the times when observations were made being 93 per cent.

The records show that at both Base Camp and ice-cap stations the weather did not depart widely from the normal for the time of year. The only exception was the rainfall, which must have been considerably above average at the Base Camp (as it was at Fagurhólsmýri), and which on Vatnajökull, had continuous records been made, might well have proved to be exceptional.

SNOWSTORM DURING THE NIGHT OF APRIL 25–26, 1950

Heavy snow, accompanied by strong winds, occurred widely south of the Thames, during the early morning of April 26, damaging trees and causing considerable disruption of traffic and telephone services. The amounts of undrifted snow reached or exceeded 6 in. in depth at 0700 (all times are G.M.T.) over a narrow belt extending roughly from Faversham (Kent) to Salisbury, as shown in Fig. 1. A rainfall map for the 24 hours ending at 0900 on April 26 is also given, as Fig. 2, and this shows that there was a good deal of rain in addition to the snow.

The weight of the wet snow, which tended to stick, together with the wind, caused destruction to trees, shrubs, telephone poles, *etc.* The wind was northerly. In north-east Hampshire it was noted by Mr. Poulter that telegraph wires set in the direction of the wind were not much affected, whereas the damage occurred where they were at right angles to the wind, *i.e.* from west to east. The wind reached gale force at times. Details of the times and directions of the highest gusts at anemograph stations in the district are set out in Table I.

TABLE I—HIGHEST GUSTS RECORDED AT ANEMOGRAPH STATIONS ON THE NIGHT OF APRIL 25–26, 1950

Station	Highest gust		Time
	°true	kt.	G.M.T.
Manston	170	30	0200
Croydon	90	28	0050
Calshot	350	53	0315
Boscombe Down	340	39	0300

*Large areas of which are at an altitude of over 4,000 ft. The mean altitude of the observing stations was 3,000 ft.

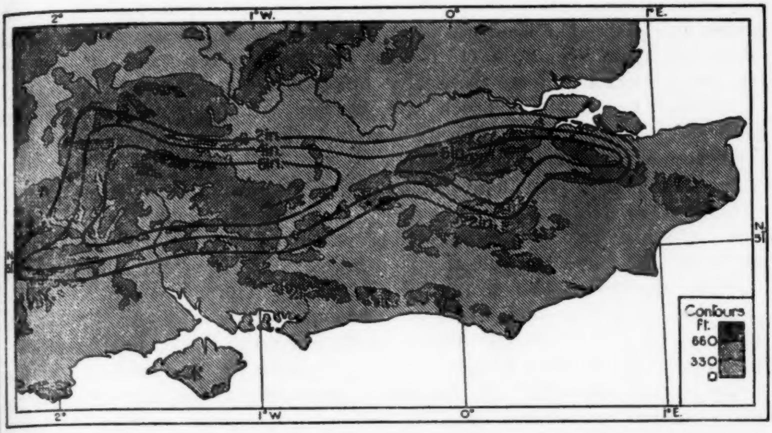


FIG. 1—SNOW DEPTH IN INCHES ABOUT 0700 G.M.T., APRIL 26, 1950

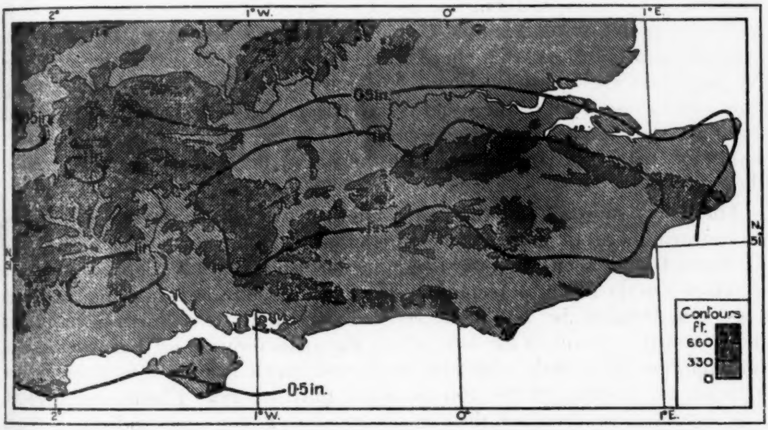


FIG. 2—RAINFALL IN INCHES, 0900 G.M.T., APRIL 26, 1950

Two photographs are reproduced by courtesy of Mr. R. M. Poulter (see photographs between pp. 228-9) showing (*a*) telegraph wires sagging under the weight of snow at South Farnborough and (*b*) a large branch newly severed from a tree at Aldershot. The latter was taken at 1130 when much of the snow had disappeared from the trees. Other photographs contributed by Brigadier R. E. Fryer show (*c*) a French Bristol Freighter at Blackbushe Civil Airport—the photograph was taken at about 0900—the two Frenchmen are brushing 6 in. of snow off the wings preparatory to taking off; (*d*) the Brigadier's garden near Camberley at about 0700, with the thick coating of snow on the sagging telegraph wires and on the trunks of the trees and the vertical surfaces of wire netting, as

well as on all horizontal surfaces. He says:—" the level depth of the snow in my garden was 5½ in. The wind was north and the snow stuck easily to the vertical sides of the chimneys on the north side. The damage to trees in our area was very great, the chief sufferers being silver birch and poplars. . . . In the grounds of the Staff College large beech trees probably 18 in. or more in diameter crashed." The last photograph shows the thickness of the snow on the north side of a small tree.

The Observer at Farnham (Boundstone), Mr. Hampton Brown, writes:—" Hundreds of trees were brought down or else dropped major branches from the weight of snow. Telegraph poles and wires were dragged down or snapped off, trains and buses stopped and in some parts electric light failed." From Farnham (Rowledge), Mr. D. M. Gordon says:—" The snow-storm . . . caused great damage to trees and shrubs . . . Brooms suffered severely. In this area there appeared to be an unbroken sheet of snow up to Dockenfield (3 miles to the south) as the trees and hedges were coated to their tops and minor bushes and plants pressed down flat." At Amesbury (Boscombe Down) the snow blocked the opening to the pressure tube of the Dines anemograph, making the record defective, and just after 0200 the Meteorological Officer climbed the mast in a strong wind to clear it.

The following is an extract from a notice sent to subscribers on May 6 by the Telephone Manager, G.P.O., Guildford:—" The full extent of the interruption to the telephone system, caused by the snowstorm of April 26, has now been assessed, and it is clear that the damage is heavier than was at first thought. No part of the Guildford Telephone Area has escaped and over 11,000 exchange lines (about one-third of the system) have been affected. The damage exceeds anything that has ever been experienced in these parts before, and presents a state of emergency comparable with the worst effects of enemy action during the war."

The heavy snowfall was the culmination of two wintry days resulting from an outbreak of arctic air from a very high latitude, following a track to the east of Greenland and then directly over the British Isles. A depression which developed to the north of Iceland on the 22nd moved south-east and deepened. On the morning of the 24th it was centred over the western North Sea and then it performed a circuit to the left. Fig. 3 shows its position off East Scotland at midnight on 25th–26th, and also its curved track from the morning of the 25th till the evening of the 26th, when it filled up near Flamborough Head. The figures in brackets are the central pressures at the times indicated. Snow fell widely on the 24th and 25th, including the south-eastern districts, where there was appreciable snow lying on the morning of the 25th, though it quickly melted. When the much heavier fall occurred on the following night the supply of cold air had already been cut off and the temperatures over Scotland at midnight (Fig. 3) were 10°F. or more higher than those of 24 hours earlier, the rise being as much as 14°F. at Dyce and 13°F. at Lerwick.

The heavy snowfall was due to the depression shown in the English Channel in Fig. 3, which also indicates the track of centre and the central pressure at various times. It existed in an incipient form over Central Ireland at 1200 on the 25th, moving south-east as a small secondary disturbance, developing a closed isobar at 1500 near the south-east Irish coast, and then turning eastward into the English Channel and later moving north-east as shown. At midnight it was raining in the London area but soon afterwards this turned to wet snow.

At midnight the wet-bulb temperature at London Airport was 36°, and the subsequent fall to near freezing point in the same air mass as the rain turned to snow may be attributed to snow falling into the layer. Most of it fell within six hours. In the Midland area there was a calm fair patch with keen frost.

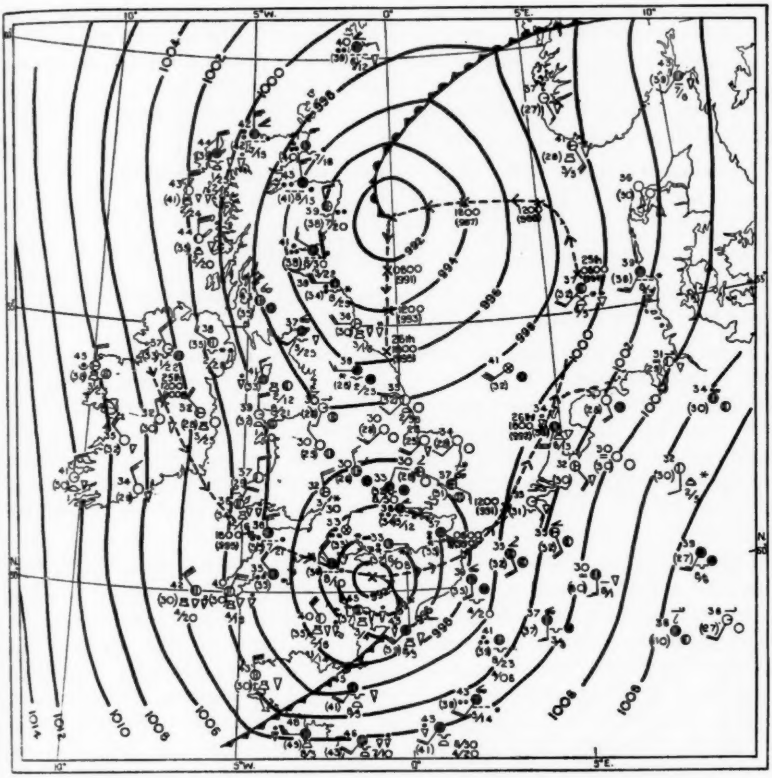


FIG. 3—SEA-LEVEL SYNOPTIC CHART, 0001 G.M.T., APRIL 26, 1950
Depression tracks are indicated by broken lines
Figures in brackets are the central pressures in mb. at the times indicated

As in the case of the severe April snowstorms of 1908, 1917, and 1919, and various other spring and winter snowstorms, the associated depression developed in polar air, forming in a region of steep horizontal temperature gradient although there was no definite pre-existing front. The cold front shown on the chart developed over Ireland simultaneously with the depression and swung round it. There was no definite warm front, but a diffuse frontal zone shown by temperature and dew point. On the previous evening at 1800 the dew point was 45° at Lizard and 44° at Scilly. When a cold front advances through a zone of this type it may assume the structure of an occlusion, but there are no definite criteria either for putting in a warm front in the diffuse zone or for turning the cold front into an occlusion. In this case the front

resembled an occlusion close to the centre of the depression but it would be an unnecessary complication to alter the name of this portion of it.

In the case of warm-sector depressions and some occluded depressions the maximum rainfall to the left of the track can be explained mainly in terms of duration, but unless the air in the warm sector is already saturated in a thick layer extending well above freezing level the maximum rainfall is likely to be at an appreciable distance from the sea-level front, falling through the cold air. In the present case there was no clearly discernible warm front, but within the area of marked convergence ahead of the depression there was some warm air advection aloft, of a quasi-frontal type, shown by the veer of wind with height at Larkhill at 2100 on 25th, given below:—

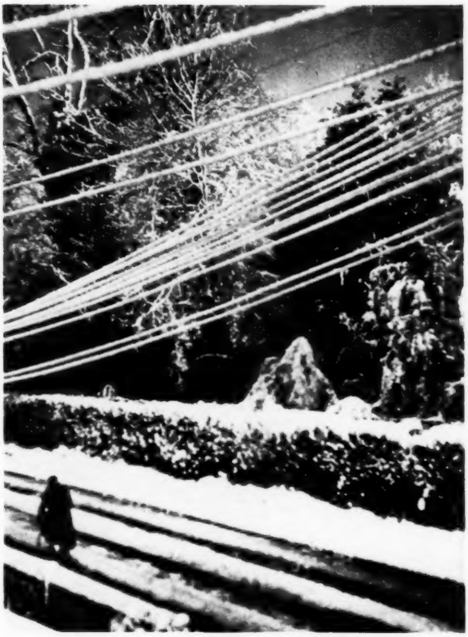
TABLE II—UPPER WINDS AT LARKHILL, 2100 G.M.T., APRIL 25, 1950

Pressure (mb.)	900	850	800	750	700	650	600	550	500
Wind direction (°true)	125	160	208	217	225	231	240	237	241
Wind speed (kt.)	14	13	16	18	25	28	29	32	40

The veer with height was most marked below the 850-mb. surface, and the lapse rate in that region was stable.

Even apart from frontal or quasi-frontal action, the circulation round the centre must tend to carry the air carrying most of the condensed moisture to the left of the track. Convergence probably has a maximum at the isallobaric minimum, but there may easily be a lag between the maximum convergence and the maximum precipitation, since it takes time to form a thick and unbroken cloud layer extending far above freezing level. When snow-flakes first form at a low temperature they are small and the time taken for them to fall through the rising air is not negligible.

Fig. 4 shows the 1000–500-mb. thickness lines (in feet) for 0300 on the 26th, and also a few sea-level isobars, which are a little different from those at midnight, and the sea-level fronts at 0300. The thickness lines are also isotherms of the mean temperature of the column of air in the layer. The winds plotted are the vector differences of wind between 950 and 500 mb. which correspond roughly to the " thermal " winds. The outbreak of arctic air formed a cold tongue from north of Jan Mayen across the eastern districts of Great Britain to France. This still existed on the morning of the 25th, the day before the snowstorm, but within the tongue there was a closed cold pool round Leuchars, where the thickness was 16,710 ft. Warm air was then advancing towards Scotland from the north-east and the cold pool moved slowly south-west although it was decreasing slightly in intensity and the movement of its associated upper depression probably induced the secondary over Ireland which gave the snowstorm. The thickness at Aldergrove dropped by 60 ft. between 0300 and 0900, and the sea-level pressure by 3 mb. During the night the cold pool moved quickly south behind the deepening secondary, and it undoubtedly played a vital part in the deepening process and in the change of the direction of movement. At 1500 on the 25th the thermal wind to 500 mb. at Larkhill was NW. 56 kt. and 12 hours later it was SSE. 12 kt. On the 26th the cold pool turned eastward behind the sea-level depression and degenerated to a minor cold tongue subsidiary to the main cold pool over the North Sea. This was formed from the more southerly part of the original cold tongue, which moved eastward on the 25th.



Reproduced by courtesy of R. M. Poulter

TELEGRAPH WIRES SAGGING UNDER THE WEIGHT OF SNOW AT SOUTH FARNBOROUGH, 0700 G.M.T., APRIL 26, 1950

Reproduced by courtesy of R. M. Poulter

BRANCH SEVERED FROM A TREE AT ALDERSHOT, 1130 G.M.T., APRIL 26, 1950
(see p. 225)

Reproduced by courtesy of Brigadier R. E. Fryer

BRUSHING SNOW OFF A FRENCH BRISTOL FREIGHTER AT BLACKBUSHE CIVIL AIRPORT, AT ABOUT 0900 G.M.T., APRIL 26, 1950

Reproduced by courtesy of Brigadier R. E. Fryer

TUDOR HOUSE, YATELEY, CAMBERLEY, SURREY, AROUND 0700 G.M.T., APRIL 26, 1950
(see p. 225)

Reproduced by courtesy of Brigadier R. E. Fryer

SNOW ON THE NORTH SIDE OF A SMALL TREE, AT TUDOR HOUSE, YATELEY, AROUND 0700 G.M.T., APRIL 26, 1950

(see p. 225)

Crown copyright

METEOROLOGICAL OFFICERS OF THE NETHERLANDS' OCEAN WEATHER SHIP *Cumulus* AT STATION JIG, APRIL 1950

To face p. 229]

NETHERLANDS' OCEAN WEATHER SHIP *Cumulus* AT STATION 'I', APRIL 1950

Reproduced by courtesy of Capt. A. W. Ford

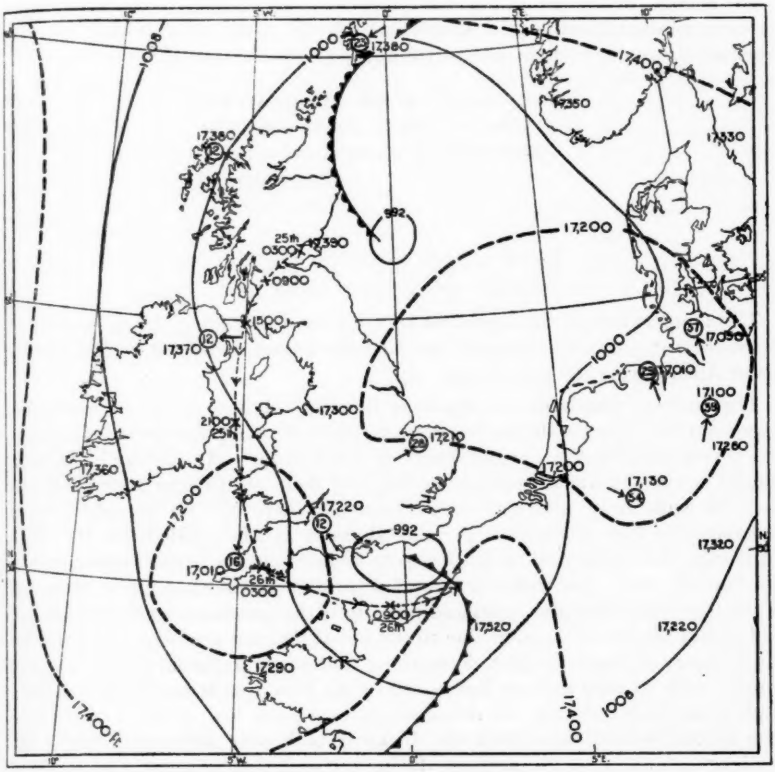


FIG. 4—THICKNESS LINES OF THE LAYER 1000–500 MB., AND SEA-LEVEL ISOBARS, 0300 G.M.T., APRIL 26, 1950

Directions of " thermal " winds of the layer 950–500 mb. are indicated by arrows; speeds are given in the circles in knots

The track of the cold pool is indicated by the thin broken line

It is interesting to note how exceptionally cold was the Arctic air stream which flowed over the British Isles on April 24. Table III gives the temperature recorded on that day at various pressures compared with the average temperatures at corresponding pressures for April for the period 1942–49.

TABLE III—COMPARISON OF UPPER AIR TEMPERATURES ON APRIL 24, 1950 WITH AVERAGE TEMPERATURES FOR APRIL

	April 24, 1950	Average April 1942–49	Difference
mb.	°F.	°F.	°F.
500	−23	− 5·3	17·7
600	−17	10·9	27·9
700	− 2	23·7	25·7
800	12	32·9	20·9
900	24	41·1	17·1

Dr. Belasco, in a paper on the characteristics of air masses over the British Isles to be published shortly as a *Geophysical Memoir*, gives the following data for April in direct polar air in south-east England, for the period 1931–45.

TABLE IV—UPPER AIR TEMPERATURES FOR APRIL IN DIRECT POLAR AIR OVER SOUTH-EAST ENGLAND, 1931–45

	Average	Lowest recorded
mb.	°F.	°F.
700	2	−2
800	15	12
900	28	24

The temperature in the upper air in the period preceding the snowstorm of April 26, 1950, therefore exactly equalled the lowest registered in direct polar air in April during the period 1931–45.

The modern emphasis on thickness lines in relation to development has decreased the apparent distinction between polar-air and polar-front depressions, but nevertheless there are real differences of behaviour and structure in the most typical cases. (It was always recognised that there are intermediate cases and that, as with most atmospheric phenomena, there are no sharply defined categories.) The polar-air depression deepens quickly, aided by the high lapse rate, but the period of development is short and the central pressure does not become really low unless a frontal depression is absorbed. The distortion of the thermal field is also rapid and this affects the movement of the depression. This rapid distortion is partly due to the initial thermal gradient being smaller on the average than in frontal depressions, and partly to the fact that the warm tongue with its crest over or just ahead of the rain area is maintained or even slightly intensified during the development of a polar low, whereas in the case of a typical polar-front system the thickness both over and just ahead of the sea-level centres generally decrease during the occlusion process. This is due to the fact that the air in the warm sector is usually slightly stable even when saturated, so that temperature at a fixed pressure is reduced when the air ascends. So long as this cooling is slight, it cannot markedly retard development. The importance of latent heat is enormous, whatever the precise lapse-rate, but it has to be considered in relation to the horizontal temperature gradient. The conversion of potential into kinetic energy requires that the ascending air should be on the whole warmer than the descending air. The charts show up the relative warmth of the precipitation area in the example we are discussing. After the snow the sky cleared quickly and in some areas there were a few hours with almost no cloud and intensely blue sky, indicating that some of the cold air was subsiding.

When the secondary first formed, the general conditions were showery, but there was some continuous snow close to the incipient centre. Aldergrove had 10 mm. equivalent rainfall in the 24 hours ending at 2100 on the 25th, but the precipitation was greater when the depression had become deeper and had crossed a warm sea surface. We have seen that the 2100 Larkhill wind observation showed a warm-front type of structure with advection from the west Channel area, where the surface temperature and dew point were relatively high. The warm tongue was formed mainly by advection but convection from the sea

surface was operating also. The relationship between cumulus convection and large-scale ascent is not yet really understood. Thunderstorms sometimes amalgamate into quite large rain areas, often with further thunder for a time (with lightning nearly all in the clouds), and there is normally an active depression or trough moving north or north-east in summer or autumn. Energy released in the form of irregular vertical movement is dissipated by friction, but the warming of the upper layers by the release of latent heat must have some significance for general development, though its scale is small in our area.

VARIATIONS OF MEAN AIR TEMPERATURE AND HOURS OF SUNSHINE ON THE WEATHER SLOPE OF A HILL

By L. P. SMITH, B.A.

Three climatological stations are situated within $7\frac{1}{2}$ miles of Aberystwyth, *viz.*:—

	Height above M.S.L. ft.
Aberystwyth, Health Resort Station	12
Aberystwyth, Plant Breeding Station, Crop Weather Station	452
Llety-evan-Hen, Crop Weather Station	950

Comparable daily records are available for over 20 years. In general terms, these stations can be regarded as lying on the slope of a hill-side facing south-west, (*i.e.* a weather slope as distinct from a lee slope).

The daily mean air temperatures, computed from the arithmetical mean of the maximum and minimum, have been examined on a monthly basis for the years 1929–48, together with the mean monthly total sunshine hours. These 20-yr. monthly and annual means show the following comparisons.

TABLE I—COMPARISON OF MEAN AIR TEMPERATURES AND SUNSHINE HOURS AT STATIONS ON THE WEATHER SLOPE OF A HILL

	Mean air temperature					Mean monthly sunshine hours				
				Difference					Ratio	
	12 ft.	452 ft.	950 ft.	12 ft. to 452 ft.	12 ft. to 950 ft.	12 ft.	452 ft.	950 ft.	452 ft. to 12 ft.	950 ft. to 12 ft.
	degrees Fahrenheit					*hours*			*per cent.*	
January	41·08	39·61	37·67	1·47	3·41	59·15	58·89	53·19	99·6	89·9
February	40·65	39·20	37·17	1·45	3·48	75·17	71·59	66·73	95·2	88·8
March	43·93	42·91	41·47	1·03	2·47	130·26	126·32	119·01	97·0	91·4
April	47·54	46·25	44·52	1·29	3·02	158·78	153·65	142·33	96·7	89·6
May	52·27	51·11	49·49	1·15	2·79	197·86	191·75	181·63	96·9	91·8
June	57·45	55·99	54·29	1·45	3·15	194·28	190·92	177·89	98·2	91·6
July	59·95	58·40	56·41	1·55	3·53	151·89	145·70	130·75	95·9	86·0
August	60·81	59·17	57·41	1·65	3·40	174·48	165·49	152·53	94·8	87·4
September	57·85	56·19	54·21	1·66	3·63	134·12	127·86	116·43	95·3	86·8
October	52·05	50·41	48·35	1·64	3·69	100·38	95·99	86·37	95·7	86·0
November	47·07	45·54	43·64	1·53	3·43	56·37	55·71	49·86	98·8	88·5
December	43·30	41·99	40·07	1·31	3·23	48·45	48·84	43·47	100·8	89·7
Year	..	..	..	1·43	3·27	..	..	..	97·12	88·96

These results are also shown in Figs. 1 and 2. The mean annual differences in temperature correspond to a fall of 1°F. per 308 ft. for the 12-ft. to 450-ft. rise, and 1°F. per 288 ft. for the 12-ft. to 950-ft. rise. The normal rule of thumb lapse of 1°F. per 300 ft. is therefore not greatly divergent from the observed results for these stations. The fall in temperature with height is least noticeable in spring, especially March and May, and most in summer and autumn.

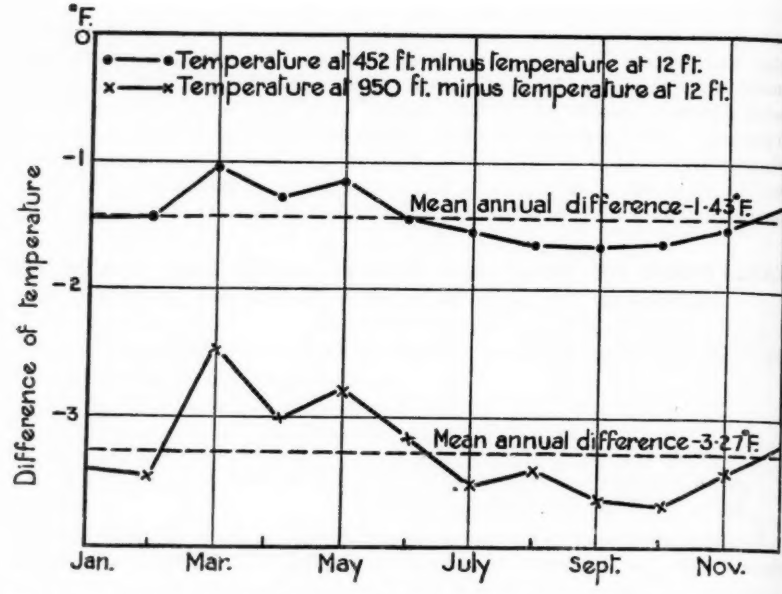


FIG. 1—DIFFERENCE OF MEAN MONTHLY AND ANNUAL TEMPERATURES AT STATIONS ON THE WEATHER SLOPE OF A HILL

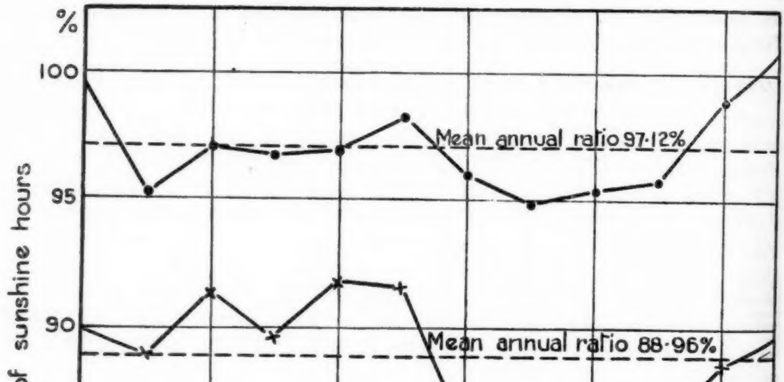


FIG. 2—RATIO OF SUNSHINE HOURS AT STATIONS ON THE WEATHER SLOPE OF A HILL

The mean annual sunshine ratio does not vary linearly with height, in fact, the above figures fit a formula:—

Decrease in percentage with height $=0{\cdot}22h^{7/4}$

where h is measured in hundreds of feet. The decrease is most apparent in late summer and early autumn, it is least at 452 ft. in winter and at 950 ft. in spring and early summer.

METEOROLOGICAL RESEARCH COMMITTEE

The tenth meeting of the Physical Sub-Committee was held on May 31, 1950. The report on the measurement of temperature and humidity gradients in the first hundred metres at Rye[1] was discussed. A paper by Dr. Robinson and Mr. Rider on the transfer of heat and water vapour above a surface of short grass[2] was also considered.

Other branches of meteorology were represented by a paper on drop-size distribution in cloud[3] and by a paper by Miss N. Carruthers which summarised the results of some upper air soundings at Nairobi[4].

[1] *Met. Res. Pap., London,* No. 546
[2] *Met. Res. Pap., London,* No. 547
[3] *Met. Res. Pap., London,* No. 559
[4] *Met. Res. Pap., London,* No. 554

ROYAL METEOROLOGICAL SOCIETY

At the meeting of the Society on May 17, 1950, with Mr. L. C. W. Bonacina, Vice-President, in the Chair, papers were read by Dr. J. S. Forrest on "Variations in thunderstorm severity in Great Britain" and by Mr. S. Morris-Bower on "Recent work of the Thunderstorm Census Organization".

Dr. Forrest's paper describes the relation between the number of break-downs caused by lightning over the whole of the British Grid system of high-voltage transmission lines and the number of days on which thunder was heard at eight meteorological observing stations, Renfrew, Eskdalemuir, Tynemouth, Birmingham, Kew, Southampton, Stoneyhurst and Long Ashton, selected so as to represent the area covered by the Grid so far as possible in relation to the density of the grid lines. Dr. Forrest explained that break-downs might occur when lightning struck either the earthed line or one of the power lines and led to a flash-over across the insulators of the power lines or from power line to earth line. A lightning strike might occur to a line without causing a break-down. He considered that the Grid would intercept strokes falling within a triangle with vertex on the line and base twice its height.

He gave tables and figures of the thunderstorm days observed at all the eight stations and total break-downs in each month and year of the 14 years, 1933–47. The total numbers of break-downs in each year followed quite closely, though with a much greater range, the thunderstorm days in each year and the two had a correlation coefficient of 0·74. The two sets of monthly totals were also very similar, with correlation coefficient of 0·97, though again the break-downs had a greater range.

The diurnal variation of break-downs had a primary maximum at 1600–1700 G.M.T., a very secondary one between 0300 and 0600, and a minimum between 0700 and 0900. The meteorological data for comparison with this were available

only for Kew* and they revealed a maximum of thunder somewhat earlier in the afternoon but no early morning secondary maximum.

Dr. Forrest ascribed the correspondence between the two sets of data, with a greater range for break-downs, to a power-law relationship of the form $N=kT^s$ between N the number of break-downs, T the corresponding number of thunderstorm days, k a constant, and $S(>1)$ an index which he termed the "severity index". He showed that S was about 1·9 for the annual variation and about 1·4 for the monthly one. The difference between the two indices he ascribed to the monthly totals being dependent on the different characteristics of winter and summer thunderstorms.

He concluded by stating he considered that statistics of "thunderstorm days" were misleading as a measure of the total severity of thunderstorms and that a better measure was obtained by applying an appropriate severity index to them.

Mr. Morris-Bower said he considered statistics of thunderstorm days based on observations of "thunder heard" were convenient but weak, as whether an observer heard thunder or not depended very much on the observer's location and assiduity. He had found it was difficult to draw any charts based on days of "thunder heard" as the number of days over a period could vary by 50 per cent. between stations three or four miles apart. He much preferred the more definite observations of thunder overhead which were recorded by observers for the Thunderstorm Survey. He described the methods of collecting and plotting the data used by the Survey.

The relation between the number of observations of overhead thunder obtained by the Survey and Dr. Forrest's Grid break-downs was, he explained with figures, very good, but the afternoon maximum of break-downs was two hours later than the overhead thunder maximum and the monthly averages did not show the sharp peak in July that the break-downs did. Better correspondence was shown by the annual variation of the areas covered by "overhead" storms. He showed charts of areas of "overhead" thunder for the year 1932 and for the annual average and also charts of isochrones of overhead thunder for a particular day.

Mr. Shipley said a more reliable statistical index of the severity of lightning than "thunderstorm days" was much needed as there was a very large variation in the frequency of lightning flashes in individual storms; it was possible to have 120 flashes a minute. He thought Dr. Forrest's criterion was the best yet produced but also that the minor distribution lines were more liable to damage. In view of the greater winter frequency of storms in Cornwall he thought Bristol was not representative for the south-west.

Mr. Oakeshott thought it might be possible to use the data provided by an atmospheric recorder for measuring severity if it were possible to distinguish between flashes in the clouds and flashes to earth. Mr. Ryle said the break-down rates in South Africa were ten times higher than in Britain and gave a severity index 2·5 times Forrest's value for Britain. The results all suggested that the more storms there were the more severe they were. Dr. Golde said the Electrical Research Association was investigating the relation between the line break-downs and the observations of the 250 stations recorded in the *Monthly Weather Report.*

Mr. Ludlam said the water content of clouds and so the severity of storms was determined mainly by temperature and it should be possible to correlate

*BISHOP, B. V.; The frequency of thunderstorms at Kew Observatory. *Met. Mag., London,* **76**, 1947, p. 108.

break-downs with temperature. The sharp afternoon maximum in break-downs showed that such thunderstorms build up quickly and he thought the early morning maximum was due to storms produced originally over France. Dr. Scrase said that, though the Kew observations of thunder heard did not show an early morning maximum, the Kew point-discharge records did.

Dr. Robinson asked what it was that the Census maps showed isochrones of, and Mr. Jacobs referred to the United States Thunderstorm Project results which showed the movement of thunder cells of diameter about three miles which developed, died away, and set off similar cells.

Dr. Forrest, in his reply, said he had estimated from the frequency of flashes that about one flash in twenty-five to a grid line caused a break-down and explained to Mr. Gold that the average length of line concerned is about twenty miles. The early morning maximum was not confined to incidents in coastal areas.

Mr. Morris-Bower said the movement shown by the isochrones was of a thundery tendency, and that the census had found that an early morning maximum of overhead storms was most pronounced over the western part of the country.

LETTERS TO THE EDITOR

Frequency of wind and radiation frosts

Mr. Hogg's article on the relative frequency of wind and radiation frosts* presents a very pessimistic picture to the fruit-grower. If one frost in four is a wind frost of the form adequately defined by East Malling Research Station then all attempts at preventing frost damage are pointless.

However, the picture is not quite so black as this because a meteorologist's general view does not conform with the view a grower must take to decide how to protect his fruit. Mr. Hogg bases his correction factor for the error involved in measuring the wind speed at 0900 G.M.T., long after the frost has finished, on measurements of the mean hourly variation of wind speed on mornings when there is a light breeze. However, on nights when this wind has persisted from 0400 at this speed a frost is extremely unlikely. On the occasion when frost has occurred the wind speed by night has probably been very much lower (particularly nearer the ground and after all how few valuable trees now bear fruit 30 ft. from the ground). The general mean therefore bears little relation to the figures that a fruit-grower requires. He wants to know, on the average, whether or not a wind was blowing at 0400 during all nights when a frost occurred in May.

Our limited experience of sitting up with a frost all night has shown us how frequently an absolute calm at dawn can become a force-2 wind at sunrise, and also how frequently a wind blowing less than 2 m.p.h. 6 ft. from the ground can prevent that disastrous pooling of cold air, which the growers dread, even on the clearest of nights.

Wind frosts do occur and are dangerous, but are less frequent than Mr. Hogg's analysis would appear to show.

National Institute of Agricultural Engineering,
Wrest Park, Silsoe, Bedfordshire,
April 18, 1950 R. J. COURSHEE

*HOGG, W. H.; Frequency of radiation and wind frosts during spring in Kent. *Met. Mag., London*, **79**, 1950, p. 42.

[It may help if I first explain how the data were extracted. The night minimum temperature and the wind force at the morning observation were extracted for each day. If the minimum temperature was 32°F. or less, the frost was assumed to be a radiation frost, provided the wind did not exceed force 2; frosts with winds above force 2 were provisionally classed as " wind frosts ". The next step was to decide what proportion of these wind frosts should in fact be classed as radiation frosts because of the diurnal increase in wind speed between the time of minimum temperature and the morning observation. The method was explained in the article, but I would emphasise that Table I refers only to days when the mean hourly wind speed fell (at about 30 ft.) below 7·5 m.p.h. around dawn; on most of these days the wind speed was well below this for the whole of the time.

I have re-computed Table I for the nights on which frost occurred, with the following result:—

	0500	0600	0700	0800	0900
	miles per hour				
March	3·5	3·5	3·9	4·3	5·8
April	2·4	2·2	2·6	3·3	4·9

Only 2 frosts occurred in May.

These mean wind speeds give the following correction factors: March 0700, 4/50; March 0900 23/50; April 0700, 2/50; April 0900, 25/50. There would therefore be no appreciable difference in the frequency of wind frost in March using these criteria, but the frequency of wind frost in April would be increased.

I agree that there would probably be little damage at 30 ft. on most trees, and for that reason I suggested that the use of 7·5 m.p.h., instead of 5 m.p.h., as a limiting value was probably no disadvantage.

On general grounds Mr. Courshee's letter raises the problem of the application of meteorology to agricultural problems. I think it is now generally agreed that special observations are needed for these problems, and I understand that more of them are being made. It will, however, be many years before there are sufficient of them to use as " normals " (if this term can be used in connexion with agricultural meteorology, where almost every site is unique). Meanwhile, how can the meteorologist best help the agriculturist? One way is to use standard observations, making estimates where the original data are not in a form suitable for direct application to agriculture. Another possiblity, which I think has not yet been tried, is to estimate the frequency of the synoptic situation which is likely to produce the agricultural hazard.—W. H. HOGG]

Temperature rise on clear mornings

Mr. Jefferson, in his interesting article in the *Meteorological Magazine* for February 1950*, says that the curves on p. 38 take the general form of a sine curve. But the top curve, which runs off to infinity, is more like part of a secant curve.

If the influx of energy throughout the year, as represented by Gold's numbers, varies as an approximate sine curve, say

$$y = a + b\sin x$$

then, neglecting the annual variation in the length of the hours of sunshine, one would expect the " hours from sunrise " curve to take the form of the reciprocal function, *i.e.*

*JEFFERSON, G. J.; Temperature rise on clear mornings. *Met. Mag., London*, **79**, 1950, p. 33.

$$y = \frac{1}{a + b\sin x}$$

This equation gives curves similar to the top curve on p. 38 when $a \leqslant b$, and it gives curves similar to the others, *i.e.* with a flat minimum and pointed maximum, when $a > b$

Calshot, Southampton, April 20, 1950 G. A. INGLIS

[Mr. Inglis in his comments has provided a general formula which appears to fit the curves given in Fig. 3. My remark that they followed the general form of a sine curve is perhaps somewhat open to misinterpretation. My purpose in drawing the curves of best fit to the points plotted was to ascertain the corrected monthly mean values of times from sunrise given in Table II, and at the time I made no attempt to provide a formula for the curves but intended to note in passing that most of them bore a general resemblance to a sine curve. However, the formula given by Mr. Inglis applied to the curve for 0·5 cm.^{2} of energy in Fig. 3 as an example becomes, assuming maximum in December,

$$y = \frac{1}{0{\cdot}37 + 0{\cdot}15\sin\frac{\pi}{6}(m-3)}$$

where y is the monthly average time from sunrise for sunshine to provide energy equivalent to 0·5 cm.^{2} in the month m (numbered January=1, February=2, March=3, etc.) and constants a and b are equal to 0·37 and 0·15 respectively. Values for a and b can be evaluated for each of the curves given, and similarly this could be done for other stations with different soil characteristics giving monthly values different from those of Table II.

Pursuing this idea it should be possible to obtain the monthly values for other stations by ascertaining suitable values for constants a and b thereby short-circuiting the somewhat long procedure for obtaining them by the original method as outlined in the paper. This would make the results of more general application.—G. J. JEFFERSON]

NOTES AND NEWS

Tropical rainfall from cloud which did not extend to the freezing level

In the issue of the *Meteorological Magazine* for October 1948, Mr. A. C. Best asked for authentic cases of rain in the tropics from cloud which did not extend up to the freezing level. The following notes have been contributed by Meteorological Officers in the West Indies.

Mr. Wallace of the Meteorological Office, Nassau, Bahamas, supplies the following comments: " There is not the slightest doubt that precipitation in quite appreciable amounts occurs fairly generally in the Bahamas area from cloud, usually a combination of cumulus and stratocumulus, with very little vertical development, and that large amounts of summer rainfall result from cumulus which, although well developed, does not reach the freezing level at approximately 15,000 ft. Instances of the latter are rather difficult to substantiate as they are for the most part of a transitory nature but the winter type of precipitation occurs under a marked anticyclonic inversion which persists almost throughout the dry season, broken only by the passage southwards of occasional cold fronts. The base of the inversion is remarkably constant between 4,500–6,500 ft. and above it humidities are extremely low, frequently less than 10 per cent. Accurate reports have been recently obtained of this

cloud structure on occasions of precipitation by aircraft operating in this area. The most striking example so far occurred on December 15, 1949, when showers were reported from a mixed layer of cumulus and stratocumulus base 1,500 ft. top 5,300 ft. 3.3 mm. of rain were recorded at Oakes Field, Nassau, in two showers around the dawn period (0930–1020 G.M.T.) and 1219-1255 respectively. The freezing level at the time was 15,000 ft. At 1500 the Miami radio-sonde gave the base of the inversion at 840 mb., temperature 46°F. and dew point 43°F. The top of the inversion was at 790 mb. with a temperature of 57°F. and a dew point of 18°F. This sounding showed no appreciable change from the previous one twelve hours earlier. The sky above the inversion was completely clear of cloud. Another instance was reported by a B.O.A.C. pilot at 1500 on January 11, 1950, five miles north-east of New Providence en route to Bermuda. Heavy precipitation was observed on this occasion down to the surface from cloud whose tops did not exceed 6,800 ft. The freezing level was 13,500 ft. The Miami radio-sonde indicated an inversion between 810 mb. and 750 mb., temperatures 46°F. and 50°F. respectively."

In addition an analysis was made at Piarco, Trinidad, of cloud tops reported from pilots flying round the triangle, Trinidad, Barbados and Grenada. On 75 per cent. of days in 1946 cloud was reported not to reach the freezing level. Yet at Seawell, Barbados, in 1946, there were 184 days with rain; at Piarco, Trinidad, there were 236 days with rain; and at Pearls Airfield, Grenada, there were 210 days with rain: evidence that a fair proportion of the rain fell on days when the cumulus did not extend to the freezing level.

A particular case may be mentioned: On March 22, 1948, an airline pilot remarked that quite considerable rain was falling over Barbados from cloud of which the tops did not extend above 9,000 ft. (although the freezing level was 15,000–16,000 ft.). Over leeward parts of the island the rainfall for the day averaged about 8 mm., while one gauge on the eastern slopes of the island recorded the maximum reading for the day, 17 mm.

S. E. VIRGO

REVIEW

Climatology. By W. G. Kendrew. 8vo. 8½ in. × 5½ in. pp. 383. *Illus*. Oxford University Press, 1949. 30*s*.

The third edition of Mr. Kendrew's " Climate ", which appears now under the new title of " Climatology ", is very welcome and Mr. Kendrew is to be congratulated on the skilful and thorough way in which he has brought the book up-to-date.

The general arrangement is similar to that of the second edition except that there are six parts in place of ten. Of these the first three deal with the meteorological elements: insolation and temperature; atmospheric pressure and winds; vapour and its condensation (including rain, cloud, sunshine and visibility) and the last three with the climate of different regions: mountain and plateau climate; the weather of the westerlies; some climatic types (Sudan, Mediterranean and westerlies). The main change in arrangement is the combination of the three parts dealing with water vapour into a single part, and the transfer of the descriptions of local winds into Part II. This, however, does not give an adequate idea of the changes. The whole book has been almost

entirely rewritten, many of the diagrams have been redrawn and new plates and figures inserted, chapters have been added on air masses, frontal weather and the upper air, and the volume is written with much more reference to the physical causes which lie behind the different manifestations of climate. The change of title from " Climate " to " Climatology " is well justified.

Almost every part of the book has been amplified. There are new sections on the thermal properties of land surfaces—a very important factor in climatology—the heat balance of the earth, turbulence and the effect of obstacles on air currents, to mention only a few. The discussion of the " trade winds " has been carried into the upper air, with a description of the inversion; the chart of rainfall has been extended over the sea; the sections on frozen precipitation have been added to, and the effect of atmospheric pollution is discussed with a very telling photograph. The new plates include a beautiful illustration of the climatic contrast between sunny and shady slopes in the Alps(Plate 12).

The good use which the author made of his war-time opportunities in Africa is evident in many places, particularly in the interesting diagram of wind and clouds over Lake Victoria on p. 120, the influence of Table Mountain on rainfall (p. 192), the charts of the lee depression of Madagascar (p. 302) and in the photograph of cumulonimbus on the equator(Plate 6).

There is a short but useful bibliography which has also been brought up to date, though one misses reference to many of the modern meteorological atlases. The fact that the only atlas dealing with the world is dated 1899 shows that climatology still lacks adequate international organization.

The index has been entirely remade, not, in the opinion of the reviewer, an improvement. There is too much grouping of all entries under the main elements so that it becomes almost a classified table of contents. Some of the elements have twenty or thirty sub-headings and more than 100 page references. Geographical names and names of authors have been omitted entirely. For deserts one is told to " see Trade winds ", but is left guessing as to which of the twenty odd references one should see. Such words as " Geostrophic ", " Stratosphere ", " Tropopause " are not there at all. Often one needs an index to trace some minor fact rather than to find the major sections but for that this index is of little help.

In a volume of this size, of which every page is full of facts and figures, some errors are inevitable, especially when it is the work of a single author. One of the more serious is in the visibility scale on p. 267 where the descriptions of some of the code numbers are wrong; incidentally a cross-reference on p. 319 to the page where the code is given would be useful. One could wish also that the author had been more consistent about units, though admittedly there may be something to be said for training students to be, so to speak, multilingual. Isobars in inches (Figs. 42–3) take one back almost to Edwardian days. In the companion diagrams of Figs. 91 and 101 sunshine is given in one in hours/month and in the other in hours/day. There is some inconsistency, too, in some of the figures quoted in the tables such as those for Kabete with a mean monthly minimum of 40° and an extreme minimum of 41°. Discrepancies of this sort emphasise the minor trials of the climatologist and are almost inevitable where the data are based on different periods all of short length. In the bibliography Clarke has lost the " e " which he rightly had in the text, Mr. Newnham has been

credited with his wife's work on hurricanes, and Abercromby has gained an " ie " after revision by Goldie.

To ask for additions to a book already so full of information may seem ungrateful, but it perhaps may be permitted regarding a book which is likely to run to many more editions and to be a standard in its class for years to come. First, one would like an index of the stations referred to, with their geographical co-ordinates and height (not all meteorological stations are given even in a modern atlas): secondly, some indication of the periods on which the data are based (it is difficult to interpret the significance of some of the extremes without it): and thirdly, a brief glossary of terms which if it did nothing else might help climatologists to come to some agreement about the use of such words as mean, average and normal.

However, these are minor points and the book should certainly be on the shelves of all meteorologists; it brings the study of climate to life as few other books do.

E. E. AUSTIN

METEOROLOGICAL OFFICE NEWS

Obituary.—It is with deep regret that we record the death of Mr. J. C. Lister and the fellow members of the crew of the Meteorological Halifax aircraft which crashed on Achill Island off the west coast of Ireland on its return from a " Bismuth " Meteorological Reconnaissance Flight on June 16, 1950.

Mr. Lister was a Meteorological Assistant prior to his call-up for national service. He was successful in the 1949 A.E.O. competition and on his release from the Forces would have taken up appointment in an established post as Assistant Experimental Officer. He was, therefore, at the beginning of a promising career as a meteorologist. On joining the R.A.F., Mr. Lister had volunteered for observational duties in meteorological reconnaissance aircraft. He had completed his training and had been promoted to Air Meteorological Observer IV immediately prior to the accident.

His present and former colleagues in the Meteorological Office extend their deepest sympathy to Mr. Lister's parents in their loss.

Establishment of assistants—competitions.—A series of short refresher courses for assistants will begin in September 1950 at the Meteorological Office Training School. Temporary assistants who have failed in the 1950 competition for establishment should note that they will be given an opportunity to attend one of these courses. They would be well advised, however, not to wait until attending a course before " brushing up " their physics and mathematics.

The Meteorological Office, Edinburgh, has been at No. 6, Drumsheugh Gardens since 1925. Owing to expiry of lease it has become necessary to find a new home and the Office moved to No. 26 Palmerston Place on June 10, 1950.

Upper air statistics and research.—Some six years ago a section was formed at Harrow to collect and summarise upper air data for the stations at home and abroad under the control of the Office. It is of interest to look back and see how the work of this section has developed and what progress has been made.

Early in 1944 it was realised that, with the development of jet aircraft, there would be an urgent demand for information on winds at high levels all over the world. This led Dr. Brooks and Mr. Durst to devise methods by which the mapping of the winds up to 200 mb. (about 38,000 ft.) could be done by interpolation. These methods involved much calculation and occupied a great part of the time of the staff for some three years. The results will shortly be published as *Geophysical Memoir No.* 85. A complement to these maps of high-level winds in the form of maps of upper air temperatures is now in course of preparation as the second major undertaking of the section. In January, 1948, the Hollerith method of punched cards was adopted for recording and analysing the data.

Married quarters.—Reference was made in the April number to married quarters at Changi. It is encouraging to report that all U.K.-based staff serving there are now accommodated in official quarters, four being in married quarters and two single men in the R.A.F. Mess.

Falkland Islands.—During the war the Naval Meteorological Service established a meteorological office at Port Stanley in the Falkland Islands. In 1946 control of this office was handed over to the Meteorological Office and in the following year the work was extended by the addition of a radio-sonde station. Since 1944 a network of meteorological stations has been in operation in the Antarctic Dependencies under the auspices of the Falkland Islands Dependencies Survey. Following a recent reorganisation, the office at Port Stanley and the stations are being co-ordinated into a small meteorological service with headquarters at Port Stanley. This service forms an integral part of the Falkland Islands Dependencies Survey. The Meteorological Office continues to administer the radio-sonde/radar-wind station at Port Stanley.

Most of the observers at the Antarctic bases are assistants (scientific) on loan from the Meteorological Office; each base is manned by a couple of observers. News from them is sparse for the good reason that their only means of communicating with the outside world is by wireless, and the cost of sending private messages is considerable. The Falkland Islands Dependencies Survey have recently again asked the Meteorological Office to help in recruiting; a note giving particulars of the posts has been distributed.

Sports activities.—From time to time in these notes we record the progress that the Office has made in its efforts to retain the Bishop Shield. The following remarks about the Shield, and the competition for it, may be of interest to members of the staff.

The Bishop Memorial Shield was presented by the staff of the Directorate of Aeronautical Inspection in memory of the late Major P. Bishop, C.B.E., A.F.C.S., who devoted much of his spare time to the cause of sport in the Air Ministry up to the time of his tragic death in the disaster to the Airship R.101. For the purposes of the Shield Competition, the Air Ministry and the Ministry of Civil Aviation are split up into a number of divisions, which compete against one another in athletics and sports, the Shield being awarded each year to the division with the best record. Points may be gained for football, cricket, netball, lawn tennis, table tennis, swimming, chess and athletics. Each competition is brought to a close with the Annual Sports, which will be held this year on Wednesday, August 30.

The Meteorological Office won the Bishop Shield twice before the war and was again successful last year. Great efforts are being made to win it again this year and so far the number of points earned is 70. Any staff who wish to help the Office in the various events are invited to get in touch with the Sports Secretary, Mr. H. S. Scotney, Meteorological Office, Air Ministry.

Staff who have not had an opportunity of attending a sports meeting will also be interested in two other trophies competed for annually. The Simpson (Victor Ludorum) Cup was presented by the staff of the Meteorological Office in recognition of their regard for Sir George C. Simpson, K.C.B., F.R.S., and his interest in Air Ministry sports. Sir George Simpson retired from the post of Director of the Meteorological Office in 1938. The Cup is presented at the Annual Sports to the champion athlete in certain individual events during the year.

The W. S. Jones Memorial Cup was presented in memory of the late Mr. W. S. Jones who, in addition to being Chairman of the Staff side of the Air Ministry Whitley Council in 1927-28, was an enthusiastic helper in the efforts to finance the Air Ministry sports ground at Waddon. The Cup is awarded to the division scoring the highest number of points at the Annual Sports, in individual championship events and inter-divisional relays.

BOOKS RECEIVED

Low stratus clouds over Bangalore, by P. A. George. *Sci. Notes met. Dep. India*, **10**, No. 123. Size: 10 in. × 6½ in., pp. 14. *Illus.* India Meteorological Department, Poona, 1948. *Rs.* 2/8/- or 4s. od.

WEATHER OF JUNE 1950

Mean pressure was above 1020 mb. from the Azores and Madeira westwards to Bermuda. It was below 1010 mb. in an area extending from northern Scandinavia across the Faeroes, Iceland and southern Greenland to central Canada, and below 1010 mb. also in the south-western part of the United States; between Labrador and Hudson Bay pressure averaged about 1005 mb.

Deviations from the normal were generally small over Europe, the North Atlantic and North America. There was an excess of about 2—4 mb. over the northern part of the Mediterranean and Central Europe, and a similar excess over the Great Lakes and adjacent parts of Canada. A deficiency over the north-eastern part of the North Atlantic, Greenland, the Arctic Ocean and the northern and north-western parts of Europe, amounted to as much as 5 mb. between the Shetlands and Iceland, and to 7 mb. in the Faeroes.

The weather in the British Isles was warm generally, sunny in England and Wales and South Scotland, and mainly dry in England and Wales but very wet in north-west Scotland. During the first week a ridge of high pressure extended across the British Isles from anticyclones over south Scandinavia and Germany and maintained very warm, sunny and mainly dry weather. Local thundery rain or thunderstorms occurred, however, in southern England on the 2nd, when 2.60 in. was registered at West Molesey (Surrey) and 2.33 in. at Hampton (Middlesex), while weak, slow moving troughs off our western seaboard were associated with some rain in Ireland and Scotland from the 2nd to 4th. The period 3rd—7th was very warm; day temperatures exceeded 80°F. at some places and reached 89°F. at Squire's Gate and London Airport on the 6th. On the 7th and 8th a cold front moved south-east across the

country causing rain locally in west and north Scotland and in Ireland. Temperature fell considerably in west Scotland and Ireland on the 7th and in other districts on the 8th with the passage of the cold front. On the 8th and 9th a wedge associated with the Azores anticyclone moved in over the country, while a trough to the north-west of Scotland moved east; some rain occurred in the north-west. Subsequently an anticyclone over our southern districts moved slowly north-east, while a shallow depression west of Portugal moved north-west and an associated trough moved north. Temperature rose and mainly fair weather prevailed on the 10th and 11th. The trough continued to move slowly north on the 12th, and on the 13th a weak cold front moved south across Scotland. Thunderstorms occurred locally in the southern half of the country on the 13th. Sunshine totals were very high for the first thirteen days, particularly in England and Wales. On the 14th a trough moved south-east over England and moderately heavy rain occurred over a considerable area.

From the 15th to 23rd the pressure distribution was very complex but mainly cyclonic. On the 15th a shallow depression near Denmark moved north, while another north of Scotland moved south-east. On the 16th a secondary depression formed off north-west Scotland and moved south-east; this was followed by another secondary off west Scotland which moved east and turned north. Again from the 19th to 21st yet another disturbance near Iceland moved east and then south-east, being centred in the southern North Sea on the morning of the 22nd. On the 23rd a secondary depression moved quickly east across southern England. During this period cooler weather prevailed, with rain or showers at times, but there was little rainfall in the south-east until the 19th. From the 20th to 22nd thundery rains or thunderstorms occurred rather widely, and at times rainfall was moderately heavy locally. Scattered thundery rain occurred in south-east England on the 23rd.

On the 24th an anticyclone developed over France and a warm south-west to west type of weather was established over the British Isles which lasted until the end of the month. Atlantic depressions moved north-east off our north-west seaboard giving rain in the west and north but mainly fair weather prevailed in the south-east. Among heavy falls of rain in the last week may be mentioned 3.16 in. at Hafod Fawr (Merioneth) and 2.20 in. at Blaenau Festiniog (Merioneth) on the 26th and 2.53 in. at Achnashellach (Ross and Cromarty) on the 28th.

The general character of the weather is shown by the following provisional figures :—

	Air Temperature			Rainfall		Sunshine
	Highest	Lowest	Difference from average daily mean	Percentage of average	No. of days difference from average	Percentage of average
	°F.	°F.	°F.	%		%
England and Wales ..	92	36	+4·0	77	−2	122
Scotland	88	31	+2·8	123	0	94
Northern Ireland ..	84	39	+3·1	96	−1	106

RAINFALL OF JUNE 1950

Great Britain and Northern Ireland

County	Station	In.	Per cent. of Av.	County	Station	In.	Per cent. of Av.
London	Camden Square ..	1·35	67	*Glam.*	Cardiff, Penylan ..	1·29	[illegible]
Kent	Folkestone, Cherry Gdn.	·94	48	*Pemb.*	St. Ann's Head ..	2·18	[illegible]
"	Edenbridge, Falconhurst	1·16	53	*Card.*	Aberystwyth	2·49	[illegible]
Sussex	Compton, Compton Ho.	2·04	82	*Radnor*	Tyrmynydd	1·73	[illegible]
"	Worthing, Beach Ho.Pk.	·58	33	*Mont.*	Lake Vyrnwy	2·40	[illegible]
Hants	Ventnor, Roy. Nat. Hos.	·88	48	*Mer.*	Blaenau Festiniog ..	9·15	[illegible]
"	Bournemouth	1·12	56	*Carn.*	Llandudno	1·24	[illegible]
"	Sherborne St. John ..	1·23	58	*Angl.*	Llanerchymedd ..	1·81	[illegible]
Herts.	Royston, Therfield Rec.	1·38	62	*I. Man.*	Douglas, Borough Cem.	1·32	[illegible]
Bucks.	Slough, Upton	1·69	82	*Wigtown*	Port William, Monreith	2·54	[illegible]
Oxford	Oxford, Radcliffe ..	1·54	69	*Dumf.*	Dumfries, Crichton R.I.	2·77	[illegible]
N'hant.	Wellingboro', Swanspool	2·03	97	"	Eskdalemuir Obsy. ..	5·19	[illegible]
Essex	Shoeburyness	1·06	60	*Roxb.*	Kelso, Floors	1·72	[illegible]
"	Dovercourt	1·02	58	*Peebles*	Stobo Castle	2·82	[illegible]
Suffolk	Lowestoft Sec. School ..	1·73	96	*Berwick*	Marchmont House ..	2·60	[illegible]
"	Bury St. Ed., Westley H.	1·72	82	*E. Loth.*	North Berwick Res. ..	2·70	[illegible]
Norfolk	Sandringham Ho. Gdns.	2·37	109	*Midl'n.*	Edinburgh, Blackf'd. H.	1·69	[illegible]
Wilts.	Bishops Cannings ..	1·83	76	*Lanark*	Hamilton W. W., T'nhill	1·40	[illegible]
Dorset	Creech Grange.. ..	1·45	63	*Ayr*	Colmonell, Knockdolian	2·58	[illegible]
"	Beaminster, East St. ..	·96	42	"	Glen Afton, Ayr San ..	3·42	[illegible]
Devon	Teignmouth, Den Gdns.	·68	35	*Bute*	Rothesay, Ardencraig	2·65	[illegible]
"	Cullompton	1·33	63	*Argyll*	L. Sunart, Glenborrodale		
"	Ilfracombe	1·42	66	"	Poltalloch	3·50	[illegible]
"	Okehampton, Uplands	3·40	123	"	Inveraray Castle ..	4·66	[illegible]
Cornwall	Bude, School House ..	1·46	73	"	Islay, Eallabus ..	3·19	[illegible]
"	Penzance, Morrab Gdns.	1·36	61	"	Tiree	2·91	[illegible]
"	St. Austell	1·78	68	*Kinross*	Loch Leven Sluice ..	2·17	[illegible]
"	Scilly, Tresco Abbey ..	2·03	117	*Fife*	Leuchars Airfield ..	1·18	[illegible]
Glos.	Cirencester	1·74	73	*Perth*	Loch Dhu		
Salop.	Church Stretton ..	1·32	52	"	Crieff, Strathearn Hyd.	2·35	[illegible]
"	Cheswardine Hall ..	1·76	72	"	Pitlochry, Fincastle ..	1·39	[illegible]
Worcs.	Malvern, Free Library	2·12	91	*Angus*	Montrose, Sunnyside ..	1·21	[illegible]
Warwick	Birmingham, Edgbaston	2·21	95	*Aberd.*	Braemar		
Leics.	Thornton Reservoir ..	1·61	75	"	Dyce, Craibstone ..	1·80	[illegible]
Lincs.	Boston, Skirbeck ..	1·36	75	"	Fyvie Castle	2·30	[illegible]
"	Skegness, Marine Gdns.	1·02	57	*Moray*	Gordon Castle	1·97	[illegible]
Notts.	Mansfield, Carr Bank ..			*Nairn*	Nairn, Achareidh ..		
Derby	Buxton, Terrace Slopes	2·85	89	*Inverness*	Loch Ness, Garthbeg ..	2·54	111
Ches.	Bidston Observatory ..	1·36	62	"	Glenquoich	7·12	145
Lancs.	Manchester, Whit. Park	3·04	115	"	Fort William, Teviot ..	5·80	[illegible]
"	Stonyhurst College ..	3·41	111	"	Skye, Duntuilm ..	4·04	[illegible]
"	Squires Gate	1·51	73	*R. & C.*	Tain, Tarlogie House ..	2·23	[illegible]
Yorks.	Wakefield, Clarence Pk.	·92	43	"	Inverbroom, Glackour..	4·12	[illegible]
"	Hull, Pearson Park ..	1·58	77	"	Applecross Gardens ..	4·67	[illegible]
"	Felixkirk, Mt. St. John	1·95	89	"	Achnashellach	8·02	[illegible]
"	York Museum	1·12	54	"	Stornoway Airfield ..	2·62	119
"	Scarborough	1·53	83	*Suth.*	Loch More, Achfary ..	8·82	[illegible]
"	Middlesbrough.. ..	1·47	78	*Caith.*	Wick Airfield	1·96	109
"	Baldersdale, Hury Res.	1·53	65	*Shetland*	Lerwick Observatory ..	4·01	224
Norl'd.	Newcastle, Leazes Pk. ..	1·35	64	*Ferm.*	Crom Castle	2·35	87
"	Bellingham, High Green	2·08	90	*Armagh*	Armagh Observatory ..	2·83	112
"	Lilburn Tower Gdns. ..	1·66	80	*Down*	Seaforde	1·95	[illegible]
Cumb.	Geltsdale	2·95	109	*Antrim*	Aldergrove Airfield ..	2·37	[illegible]
"	Keswick, High Hill ..	2·63	90	"	Ballymena, Harryville..	2·70	93
"	Ravenglass, The Grove	2·94	113	*L'derry*	Garvagh, Moneydig ..	2·70	100
Mon.	Abergavenny, Larchfield	1·13	46	"	Londonderry, Creggan	2·58	[illegible]
Glam.	Ystalyfera, Wern House	4·30	114	*Tyrone*	Omagh, Edenfel ..	3·10	110